Semiconductors:
The Crude oil of the Telecommunications Revolution

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Good morning. My name is Russ Bell and I am the director of communications technology at Advanced Micro Devices, a leading manufacturer of integrated circuits in the US. You are probably wondering why a semiconductor veteran is presenting to a group of service providers and utility operators. Well, actually, it is quite simple; semiconductors will undoubtedly fuel the pending telecommunications revolution that is beginning to be felt throughout the world. To that end, it behooves all involved to have a better understanding of each other's businesses as we all embark on what will surely be a "colorful journey" into a world that will be as different in 20 years as the mainframe is different from the PC.

For completeness, I will provide a little background / commercial on AMD. AMD, founded in 1969, is the fourth largest producer of ICs in the US with annual sales of 2.4 billion dollars. AMD is probably best known for our legal wranglings with Intel over microprocessors for the PC industry. Despite the legal issues, AMD remains the world's number two supplier of 32 bit microprocessors and has helped fuel the widespread affordability of APX-based PC platforms by continuously driving the cost/performance points lower over time. But, what you may not know is that AMD is also a powerful communications company. Over 40% of our sales dollars are driven by the communications industry. For example, AMD is the world's largest non-captive supplier of telephony circuits for line cards (SLIC devices and SLAC™ devices) having shipped over 150 million of these DSP based engines that are used to provide basic telephony services in over 70 countries around the world. AMD was also named the world's largest LAN supplier in 1995 by Dataquest based on the sales of our ethernet adapter and hub products. AMD is also a supplier of wireless LANs, CT2 cordless telephony, and a variety of other communications-centric products, including the FLASH memory technology that resides in almost every cellular telephone in the world.

Just as the PC business was fueled by cost-effective semiconductors, one can expect that the communications industry will directly benefit from the advanced technology development that has driven the personal computer industry for the past decade. Microprocessors with 10 million transistors are commonplace today and communications engineers will be able to use these 10 million transistors in unique ways to solve complex communications problems. This advanced semiconductor technology that I have described will be the crude oil that powers the communications revolution through the balance of the decade and well into the next century. To that end, it is beneficial to all of the communications stakeholders to

work collaboratively to assure the availability of cost-effective communications solutions that enable the communications revolution.

Because of AMD's presence in both the PC and communications markets, we have developed a unique cross-industry view of the collision of these businesses and the multiple opportunities that will certainly arise for equipment manufacturers, service providers, and new entrants. Today, I will provide a historical view from a semiconductor manufacturer's perspective of advanced technologies and of the emerging markets and technologies that promise to alter the communications landscape forever. I will provide our perspective on these technologies and explain AMD's investment choices in these new technical marvels. Finally, I will offer a scenario of risk / reward sharing based on partnerships that transcend the traditional supplier / customer relationship and invite those of you so inclined to begin a dialog with semiconductor suppliers so that we can move the telecommunications revolution into the next century.

A Little History - or SEMI History

In 1984, ISDN was hailed as the technology that would revolutionize the communications world. According to the experts, High speed communications pipes would connect our homes and offices offering us a variety of high quality services and standard telephony products with new features. A host of equipment manufacturers and semiconductor suppliers jumped on the bandwagon. Years ticked by and the total installed base of ISDN lines at the end of 1995 in the US was less that 400k units. You don't have to be a financial wizard to understand that the ROI on this investment was less than stellar. What happened? This foil outlines some of the technical issues that hindered the adoption of ISDN technology, Suffice it to say that there were (one could say are) a host of technological factors as well as consumer demand issues that have hindered the adoption of ISDN in the US. Finally, after years of struggle, interest in ISDN has shown signs of increasing, driven by telecommuting and internet access applications.

In the local area networking arena, many of you may recall the promise of FDDI as a superior high speed LAN technology that promised to unseat the installed base of ethernet and token ring. FDDI's higher speeds and dual rings offered higher performance and redundancy in the event of a single ring failure. Years later, the sales of FDDI are an order of magnitude below those "archaic" technologies they promised to obsolete and ethernet has been enhanced to operate at 100 Mbps. A new ethernet working group has been established to push the speeds to 1 Gbps.

Similar scenarios can be replayed for ISO ethernet, 4/16 Token Ring, ADSL, Video on demand, and I am sure that each of you can add your own horror story.
Frequently, I am approached by equipment manufacturers who ask us to develop silicon solutions for new markets. Equipment suppliers and service providers have grown accustomed to the tremendous benefits of the ever improving semiconductor process technology (show foil from ITU) and have grown to expect continuous increases in logic density, computational power and memory capacity at an ever declining price point. In order for equipment manufacturers to invest more intelligently, it is important that we heed the lessons of the past.

What did we learn from these endeavors and how will we translate these lessons to actionable plans for future success?

1) Guaranteed rate of return and vertically integrated suppliers thwarted semiconductor and equipment development.

2) Incumbent technology is difficult to replace unless the value add of the new technology is several times more than the "old technology" (cellular example vs PCS, VDT vs CATV, ethernet vs. iso-ethernet, FDDI vs ethernet).

3) Semiconductor manufacturers can not always trust the forecasts / market views of our customers - one must get closer to the service provider or the end user in order to evaluate and understand business models.

4) Risk/reward sharing can encourage the development of solutions (including semiconductors) that will provide the economies of scale and scope necessary to achieve cost points that will drive demand

5) Standards are double edged swords that drive the economies of scale necessary for consumer price points but standards tend to erode margins that discourage investments in "commodity technology" Risk / reward sharing and royalty structures can assist us in meeting these challenges.

6) Consumers and businesses are not always willing to pay for new services (VOD and Time Warner trial in FL, ISDN).

These are the issues that became quite clear as we began to embrace very complex systems that are typical for the communications world. Today, the rules are changing. Deregulation coupled with advanced technologies and opportunities for new and aggressive service providers will help address many of these points.

THE OPPORTUNITIES (THE VIEW OF A PURE-PLAY SEMICONDUCTOR HOUSE)

Deregulation seems to be a step toward the elimination of the status quo in the telecommunications industry. This foil shows some of the highlights of the changes that I expect to drive the semiconductor industry.

So where are the opportunities that we see ?

The long distance market is not very interesting to a mainstream semiconductor manufacturer. The equipment required is not semiconductor intensive nor is the volume of equipment particularly large. However, the local loop / CATV infrastructure and wireless communications opportunities meet the "volume test" required by semiconductor manufacturers in order to feed their huge manufacturing machines.

The unbundling of the local loop will provide competitive service providers an opportunity to deliver advanced services to the end user. Computers sales are

targeted more and more toward the home user. Many are telecommuters or are SOHO users that require remote LAN access. Many are avid internet surfers. Remember that prior to deregulation in the US, RBOCs have been chasing the video delivery business for some time and have focused on technologies to allow them to deliver video signals over their **600 billion dollar installed local loop copper base**. The recent disappointing results of expensive video on demand and the deployment of the "death star" (DBS) has forced many to reconsider their video service plans over copper. Several companies are now considering an ADSL technology that can provide outstanding remote LAN access, telecommuting services, and internet access for a residential or business subscriber. Also, CLECs, IXCs, utilities and others may begin to offer advanced services over the unbundled copper loop. AMD is investing in the core technologies to deliver ADSL-lite™ services to both infrastructure equipment manufacturers and terminal equipment suppliers. ADSL-lite™ is a derivative of ADSL that provides symmetrical communications speeds at a price point significantly less than the costs for standard ADSL. AMD also believes that ADSL-lite™ technology can be useful for providing a more robust return channel in the noisy cable TV plant around the world, thus enabling market growth in the cable modem business.

CABLE MODEMS

The MSOs were afforded some regulatory relief in S.652 in the form of rate cap elimination that will help them fuel some of the additional investments in plant and equipment needed to provide advanced services. There has been a host of discussion about high speed internet access, remote LAN connectivity, etc., by the cable companies. In the limit, cable operators' plant and equipment requires a significant amount of rework in order to be capable of reliable high speed bi-directional transmission of data. I believe that it will be well near the end of the century before cable modem deployment will take place on a large scale (in excess of 1 M units). AMD is investing in a subset of the technology that could be used in any high bandwidth pipe to the home. AMD has made an investment in this technology with a leading cable infrastructure and networking company.

Wide Area Bandwidth

The internet is rapidly destroying the concept of "distance based pricing" for wide area connectivity. Internet voice solutions have provided "free phone" service for some time. EMAIL and file transfer are routine tasks that are performed over the internet on a daily basis and are not billed on any distance based criteria. In fact, as this ITU foil shows, the transAtlantic cable bandwidth "glut" is rather large. Clearly, this glut supports Gilder's view of the world that bandwidth is becoming cheaper and cheaper. But based on my ATT telephone credit card and recent trips to Europe, the savings are not being passed along. But it is also plausible that these artificially higher rates can not be sustained. A duopoly or an oligopoly with legislative relief may be able to maintain high margins; deregulation and innovative technologies like the internet are making the computing and communicating public aware of the "real cost of bandwidth." Indeed, if there is a glut of bandwidth that can be brought to the market by utilities, CAPs, and IXCs, it seems reasonable that the prices should fall. Ironically, could the RBOCs enter the long distance business

at its peak? Will new and unregulated entities provide the impetus that starts the pricing spiral for wide area bandwidth? If Gilder is right, this dark fiber backbone will certainly allow multimedia and advanced broadband networks to develop rapidly. The local loop bottleneck remains and this scenario re-enforces the push to develop a fatter pipe to the home and as I have mentioned, AMD is investing in this area. If the cost of bandwidth declines rapidly, this will serve as a catalyst to further drive the development of technology to enable the "last mile" of the local loop. Only time will tell how this scenario will unfold; but change in the status quo is a certainty.

Wireless

In the PCS arena, there are clearly too many spectrum "owners" chasing too few customers. The incumbent cellular providers will continue to find ways to increase their capacities and services beyond their current capabilities while PCS operators will be forced to relocate microwave users, acquire cell sites, select one of the multiple technologies, build infrastructure, and attract customers. The new technology brokers have failed to deliver low power operation and increased capacity and have fragmented the semiconductor community's investments among multiple targets thus diluting the economies of scale that are required for consumer price points. AMD has chosen to invest in mainstream cellular technology (GSM) and wireless local loop solutions as these markets support the necessary volumes required by our semiconductor operations and are synergistic with our core competencies. AMD currently has products in development targeted at these markets. We believe that this will be a huge growth area in the future, both in the US and abroad.

ATM- Asynchronous Transfer Mode or Another Technical Morass?

ATM was introduced in the late 80s with fanfare similar to ISDN. ATM has been hailed as the last networking technology that would ever be needed. And, in truth, ATM definitely has characteristics that make it suitable for a variety of applications. ATM provides a convenient way to packetize all information types including voice, video and data. ATM also provides scaleable networks and can provide various classes of service and data rates. In theory, ATM technology will allow all packets to be treated in a similar fashion as they traverse the network. In practice, it is proving rather difficult to establish standards and interoperability between multiple vendors equipment that can handle all ATM traffic types including voice, video, data, and other types of isochronous services. On the complexity chart, ATM is at least an order of magnitude more complex than ISDN; keep that in mind when you are considering the adoption rate of this technology and the role that it will play in your communications networks.

Also consider that the SONET transport technology maintains legacy compatibility with switched px64 networks thus assuring a long and colorful life for the switched based facilities that dominate the market today.

AMD has invested in ATM technology and we believe that it will be an important core competency for a variety of applications, including LAN hubs, wide area data and voice switching, and for PC applications. Although it is important to point out

that we have not yet introduced a product as we do not see the demand necessary to drive high volume silicon.

However, just as the PC has influenced the communications industry, the communications industry is beginning to influence the PC architecture. An unlikely application of ATM centers around personal computers and communications applications. As communications pipes into the PC increase in speed and deliver decreased error rates, it behooves the clever computer architect to deliver the appropriate data stream to the appropriate termination point. Specifically, video signals traveling to the PC (in either compressed or uncompressed form) could be delivered directly to the frame buffer of the PC. This avoids the traditional model of receiving the data, generating an interrupt, servicing the interrupt, running a protocol stack to "unwrap" the data, and finally delivering the data to the correct destination. If an ATM-like switching technology was developed for the PC backplane, various streams could be routed inside the PC without processor intervention (when possible), thus improving the overall performance of the PC without adding additional cost. Convergence strikes again - in an unlikely way.

Likely Scenarios

So where does AMD see the future? I will offer a few scenarios that were developed within AMD during the past few years Some will be bold; some will be tame; all will be controversial.

Pipe to the home fattens

There is little doubt that the pipe to the home will fatten. The question centers around “which technology?” Unbundling allows competitors to enter the market; the copper plant, regardless of its condition, is a significant asset and will provide a pathway to deliver advanced services to the home and business. AMD is investing in technology to enable this loop progression. Cable modems will also provide this capability, although we believe it will take longer for the infrastructure to develop to enable high speed bi-directional capability over the plant. Nevertheless, AMD has invested in an equity position and joint technology development with a leading cable equipment supplier.

Wireless grows both cellular and FRA technologies as the less well-heeled PCS entrants scramble

PCS entrants will be faced with a struggle. Consolidation will probably happen within this industry as the spectrum 'winners' scramble to generate revenue. The wireless local loop is an attractive market for limited mobility personal communications or for FRA (fixed radio access). Also, the 27+ billion dollars charged by the LECs to the IXCs for access will be a tempting business for many new entrants; wireless provides quick time to market with substantially lower infrastructure cost per subscriber. AMD has developed specialized products for the 'wired' portion of this wireless market (legacy telephones, fax machines, etc.) and is developing radio solutions that address FRA and upbanded GSM for PCS.

Deregulation fuels ROI erosion in the verticals and drives a tightening in the cost structures of both service providers and equipment manufacturers

The inevitable demise of guaranteed rate of return for service providers will reduce the ”flow of dollars” from service providers to equipment manufacturers and will result in margin pressures inside the vertically organized equipment manufacturers. This increase in competitive pressures will provide opportunities for aggressive, savvy companies that can capitalize on the discontinuity in the market. This is excellent news for AMD as we are a pure play semiconductor company that is vying for business inside vertically oriented equipment companies. These pricing pressures will encourage the captive semiconductor players to "come clean" on the real cost of their devices. These pricing pressures translate to direct opportunity for AMD and other aggressive semiconductor companies and ultimately lead to more competitive solutions for service providers.

Distance based billing begins to change

As I pointed out earlier, the significant amount of dark fiber in the world, coupled with increased competition in the long distance market will result in lower wide area connectivity charges. This fuels the multimedia revolution and on-line businesses. In a recent discussion with a major on-line service provider, their stated goal was to deliver video clips and multimedia service over the network by simply clicking on an ICON. Clearly, increased local loop bandwidth and low cost transport will be required.

Old technology hangs on longer than anticipated

In spite of deregulation, competition, and advanced semiconductor technology, old habits die hard. We are accustomed to 6 month time constants for the PC industry; we may be surprised to learn that infrastructure time constants can easily exceed 6 years. Backhoes do not obey Moore's law. Time and time again, we have learned that new technology will not win just for technology's sake. As one of my colleagues states on a regular basis, " the best lessons in life are learned over and over again." Clearly, we must be prudent with our investments and partnerships to assure sufficient ROI ROE.

Opportunities exist for strange bedfellows

To that end, I believe that strange bedfellows will be the norm in the communications industry during this tumultuous period that we are about to embark upon.

Allow me to elaborate on a "strange bedfellows" scenario that may become the norm rather than the exception for business in the future.

Assume for a moment that an aggressive young semiconductor company visited a leading RBOC and asked the RBOC to work with the semiconductor supplier (a first) to define common interfaces to their telephony equipment (let's assume line cards for class V switches as line cards are large volume items that interest semiconductor manufacturers and service providers). Let's also assume that an open

interface is defined thus allowing anyone to manufacture equipment to the specification. This is essentially analogous to the AT bus commoditization that occurred in the PC market place, which allowed a host of new innovative products to enter the market as add-in cards. The RBOC ***equipment suppliers*** would be required to adhere to this specification. At the same time, the aggressive semiconductor company would manufacture silicon that would lower the cost of this interface (as could other semiconductor manufacturers). In the limit, the cost of the hardware for the class V switch would drop significantly and would encourage the equipment manufacturers to address the cost effectiveness of their solutions or to migrate the value of their product to some other area (software, automated maintenance, etc,). This is the type of discussion and partnering arrangement that we all need to consider for the future; and there are many others that we must all entertain if we are to provide the best solutions to the market with the most added value. But, business as usual cannot continue if we are to capitalize on this historic opportunity.

However, the real question today is not what I think...it's what you think and what we can think of collectively. Many of you are embarking on new business ventures as we speak. Maybe you haven't thought of the implications of working closely with or partnering with a semiconductor vendor; I would encourage you to consider it. Also, what am I missing in my assessment of these markets? What markets have I totally missed that may dwarf the ones I spoke of earlier? I need your help to better understand your business needs and concerns. Let's continue the dialog and work together to drive the communications revolution of the next millennia.

Mr. Bell's Biography

Russ Bell currently serves as the director of communications technology, for the advanced development lab within Advanced Micro Devices, Inc., a fortune 500, California-based semiconductor manufacturer. Mr. Bell is chartered with the responsibility of determining the future direction of AMD's silicon-based products for emerging communications markets. Mr. Bell has also served in a number of capacities for AMD ranging from director, Corporate Strategic Marketing, Communications Technology to the director of North American Field applications engineering during which time he managed a group of 50 plus professional engineering / technical personnel responsible for AMD "design wins" in the PC and communications markets.

Prior to joining AMD in 1984, Mr. Bell served as an Assistant Professor of Electrical Engineering Technology at the Southern Technical Institute in Atlanta, Georgia. Mr. Bell has performed design and consulting work for Scientific Atlanta, Cox Cable, Lockheed-Georgia, and The Department of Defense. Mr. Bell holds degrees in Electrical Engineering Technology from The Southern Technical Institute and a Masters in Information and Computer Science from The Georgia Institute of Technology. Mr. Bell is a member of IEEE and a registered Professional Engineer in the State of North Carolina.

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